**Clock Algorithm**

In second-chance (clock) page-replacement algorithm the reference bit for a page is set by the hardware whenever that page is referenced (either a read or a write to any byte in the page).

Initially, all bits are cleared (to 0) by the operating system. As a user process executes, the bit associated with each page referenced is set (to 1) by the hardware. After some time, we can determine which pages have been used and which have not been used by examining the reference bits.

The basic algorithm of second-chance replacement is a FIFO replacement algorithm. When a page has been selected, however, we inspect its reference bit. If the value is 0, we proceed to replace this page; but if the reference bit is set to 1, we give the page a second chance and move on to select the next FIFO page. When a page gets a second chance, its reference bit is cleared, and its arrival time is reset to the current time. Thus, a page that is given a second chance will not be replaced until all other pages have been replaced (or given second chances).

One way to implement the second-chance algorithm (sometimes referred to as the clock algorithm) is as a circular queue. A pointer (that is, a hand on the clock) indicates which page is to be replaced next. When a frame is needed, the pointer advances until it finds a page with a 0 reference bit. As it advances, it clears the reference bits. Once a victim page is found, the page is replaced, and the new page is inserted in the circular queue in that position.

**Exercise:**

Consider the following page reference string:

```
3, 1, 4, 2, 1, 2, 4, 3, 5, 1, 4, 2, 4, 3, 1, 4, 2, 3, 2.
```

Assuming demand paging with three frames, how many page faults would occur for the Clock replacement algorithms?
Disk scheduling

Seek time — the time to move the arm holding the heads to the correct cylinder.

Example. Consider a disk queue with requests for I/O to blocks on cylinders
98, 183, 37, 122, 14, 124, 65, 67
in that order.
Exercise. Consider a disk with 101 cylinders. The queue with requests for I/O to blocks on cylinders is:

\[ 90, 50, 30, 70, 100, 40, 60, 20 \]
in order. The disk head is initially at cylinder 80 and moving upward.

By using the FCFS, SCAN, SSTF, and LOOK algorithms, determine the order in which the requests are processed and the total head movement.

<table>
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<th>Algorithm</th>
<th>Order</th>
<th># total head movement</th>
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<tbody>
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